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Evaluating the potential for catastrophic fault-rupture-related hazards affecting a key hydroelectric and irrigation region in central Asia

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The Toktogul hydroelectric and irrigation scheme is the largest in central Asia, with a reservoir containing almost 20 km3 of water behind a 230 m-high dam. Annually, the scheme generates 1200 MW of electricity that is distributed over Kyrgyzstan, Uzbekistan, Tajikistan, Kazakhstan and Russia. The scheme is vital for the economic, social and agricultural stability and development of the emerging central Asian republics it serves and, since it is no longer administered centrally as it was in Soviet times, is increasingly the focus of cross-border tensions involving competing needs for irrigation water and power supplies. Our work aims to identify and evaluate potential geo-environmental threats to this region for the benefit of stakeholders; with recommendations for measures to mitigate a range of threat scenarios, presented in a user-friendly GIS format. Most notably these scenarios involve the potential for very large magnitude earthquakes, with associated widespread slope instability, occurring on the little known Talas – Fergana fault. This structure, some 700 km long, bisects the Toktogul region within the actively (∼20 mm a-1) contracting Tien Shan mountain range and exhibits geological characteristics similar to large strike-slip faults such as the San Andreas. Historical records are limited in this inaccessible mountainous region that, until Soviet times, was occupied by mainly nomadic peoples, but do not indicate recent fault rupture. This highlights the role of geological investigations in assembling a record of past catastrophic events to serve as a guide for what may be expected in the future, as well as the inherent difficulties in attempting geological forecasts to a precision that is useful on human timescales. Such forecasts in this region must also include the presence of some 23 uranium mining waste dumps within the mountain valleys, a legacy from Soviet times, as well as arsenic-rich waste dumps remaining from an earlier era of gold mining. Many of these toxic dumps are vulnerable to seismically induced landsliding, release of reservoir water and breaching of very large (up to several km3) landslide-dammed lakes within the deep mountain valleys typical of the fault zone. The May 2008 earthquake in neighboring Sichuan, in which some 30 landslide-dammed lakes were created, may be useful in refining hazard scenarios developed from the multi-pronged analysis employed in our study. This analysis involves compiling all relevant existing data, such as seismic archives held in paper format, within the project GIS. Spatial and temporal patterns exhibited by these compiled data, together with focal mechanism determinations where possible, are combined with data on the distribution and nature of geological units to provide estimates of peak ground acceleration and the likely incidence of seismically-triggered slope instability. This compilation also identifies data deficiencies to be targeted using a portable seismometer network, geophysical and geodetic surveys, InSAR and other remote sensing data; all combined with geotechnical and palaeoseismological fieldwork. Initial results from this approach confirm the ground-shaking potential of Talas-Fergana rupture events, suggest a long-term slip rate as high as 15 mm a-1, and the occurrence of the last ground-rupturing event some 4-500 years BP. The lack of significant activity since that event suggests the Talas-Fergana structure may comprise a seismic gap within the Tien-Shan, highlighting the importance of hazard scenarios in proposing mitigation measures against potentially catastrophic threats, such as extensive pollution of irrigated lands in the Fergana Valley downstream from Toktogul on which some 10 million people depend.